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The Accuracy of Establishing the Boundaries of the Coastal Protective Strips of Water Bodies in Ukraine

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Abstract

Coastal protective strips (CPS) and water protection zones are important in protecting water and land resources in Ukraine from erosion, flooding, and other negative environmental processes. Although prior research has emphasized hydrodynamic impacts and engineering or biotic stabilization measures, little attention has been paid to the methodological accuracy of delineating CPS boundaries as required by Ukrainian law.by Ukrainian legislation. This study proposes a geodetic methodology to determine CPS widths using topographic and cartographic sources at scales of 1:10,000 to 1:5,000. The method yields boundary determinations with an approximate accuracy of 4–5 meters. The approach was tested on Lake Synevyr in the Carpathian region, demonstrating its practical applicability for environmental protection, land-use planning, and compliance with regulatory standards. Results improve precision, transparency, and legal certainty in establishing CPS boundaries, with implications for environmental protection, land-use planning, and regulatory compliance.

Keywords

Coastal protective strip; Shoreline delineation; Topographic mapping; Geodetic measurements; Boundary accuracy

Introduction

In contemporary land-management law, considerable attention is given to establishing water-protection zones and delineating coastal protective strip (CPS) boundaries. It should be noted that water protection zones are nature protection territories, which are intended for the favorable functioning of the regime of water bodies and the prevention of their pollution and clogging. Because land parcels within CPS are adjacent to water bodies, their management frequently results in violations of land and

water legislation by those granted usage rights. Despite the legal restrictions on the right of use in these territories, there are cases of land use not for its intended purpose, as well as the emergence of legal disputes on the issue of non-compliance with the established width of coastal protective strips with regulatory requirements.

The development of the dynamics of coastal erosion processes has become a serious problem in coastal areas (Brunina, Reeves and Skinke, 2011; Yamamoto, 2021; Toledo, and Crespo, 2024). The impact of the tsunami (Santos and Mileu, 2024) and soil and vegetation degradation (Correll, 2005) put the issue of protection and protection of the natural resource potential of coastal areas on the agenda (Toledo *et al.*, 2025) and conducting CPS monitoring both by ground and satellite methods (Agate, Ballinger and Ward, 2024; Pinho and Gonçalves, 2025; Quadroni *et al.*, 2022). Coastal changes and transformations affect the socio-economic development of territories (Abdyralieva and Totubaeva, 2024; Dio and Dio, 2025; Lako and Kerpaci, 2024). To reduce such impacts, both engineering coastal defenses and nature-based protection measures have been implemented (Taveira-Pinto, Rosa-Santos and Fazeres-Ferradosa, 2021; Verheyen *et al.*, 2025). In addition, the possibilities of developing an integrated approach to coastal management are currently being considered. This approach is based on the concepts of being able to exploit the potential advantages of sustainable coastal protection solutions compared to traditional methods, taking into account the dynamics of climatic conditions (Le Xuan *et al*., 2022). Some studies also consider monetary compensation mechanisms for erosion-related damages to water bodies (Michael and Coleman, 2020).

Within this context, a critical legal and methodological element of CPS regulation is accurate establishment of geometric parameters. Ukrainian national legislation specifies CPS widths based on the type and characteristics of water bodies; however, a notable gap exists in research addressing the accuracy and reliability of determining these boundaries in practice. Accurate official information on CPS boundaries and adjacent land conditions is essential for minimizing disputes, ensuring compliance, and preventing misuse of valuable coastal territories. A key methodological challenge is determining the planned position of the water cut, the reference line for measuring CPS width. The water cut must be considered in two dimensions: vertically (water-level fluctuations) and horizontally (plan-view shoreline shifts). Land management projects require the planned position of the water cut corresponding to a boundary (low-water) period, irrespective of the water's actual position at the time of survey. This creates a recurring problem: how to reliably establish the boundary water level and shoreline position when natural hydrological dynamics are highly variable. Two approaches are typically used to address this challenge. The first relies on existing topographic and hydrographic maps and plans, while the second reconstructs the boundary water level using archival hydrological data. Both methods involve uncertainties that affect the precision of CPS boundary delineation. Therefore, assessing and improving the accuracy of determining these geometric parameters is crucial for strengthening the legal certainty and environmental effectiveness of CPS implementation in Ukraine.

Thus, the development of the process of establishing the accuracy of CPS width based on cartographic and geodetic methods is a novelty of this study, which will contribute to the creation of more reliable and objective officially recognized information about CPS

boundaries and will contribute to the minimization of misunderstandings and abuses during their use.

Literature Review

The main regulatory and methodological basis for the formation of water protection zones and CPS s in Ukraine at this stage are the Water Code of Ukraine[1], the Land Code of Ukraine[2], the Law of Ukraine "On Regulation of Urban Development"[3], Resolution[4] of the Cabinet of Ministers of Ukraine dated 05/08/1996 No. 486 "On Approval of the Procedure for Determining Sizes and Boundaries" of water protection zones and the regime of conducting economic activities in them", and State building standards "Urban planning. Several state building norms and methodological documents also provide technical requirements, including DBN (1992) on planning of settlements, VBN (1993) on water protection zones for reservoirs, DBN (2014) on engineering investigations for construction, and the Methodology for Organizing Water Protection Zones of Rivers of Ukraine (Yatsyk, Tomiltseva and Filimonenko, 2004).

Legal and Regulatory Framework for CPS Width

Ukraine's Land and Water Codes specify CPS widths according to water-body type, area, configuration, and slope: small rivers, streams, and ponds (≤3 ha), 25 m; medium rivers and reservoirs (>3 ha), 50 m; large rivers and lakes, 100 m; and sea coasts, bays, and estuaries, at least 2 km from the water's edge. If bank slope exceeds three degrees, the minimum CPS width is doubled. The standard (SOU, 2009) provided for the development of CPS projects and water protection zones, taking into account socio-economic and soil factors, natural landscape, and other factors. In particular, it was supposed to determine the width of the CPS, taking into account the factors that determine: granulometric composition of the soil, forest cover, and types of forest vegetation, roughness in the absence of forest, and land types by the method of entering the relevant coefficients. However, unfortunately, it was canceled by the order[5] of the State Geocadastre of Ukraine No. 305 dated 18.06.2021. Regulations require the water-cut position for riverbank CPS to be determined relative to the boundary (low-water) period, typically the estimated low-water year with a 20-year return period.

[1] Water Code of Ukraine: Law of Ukraine (1995). Available online: https://zakon.rada.gov.ua/laws/show/213/95-%D0%B2%D1%80#Text [Accessed on 07 November 2025]

[2] Land Code of Ukraine: Law of Ukraine (2001) Available online: https://zakon.rada.gov.ua/go/2768-14 [Accessed on 07 November 2025]

[3] Law of Ukraine (2011). On the regulation of urban development activities. Available online: https://zakon.rada.gov.ua/laws/show/3038-17#Text [Accessed on 07 November 2025]

[4] Resolution of the Cabinet of Ministers of Ukraine, (1996). On Approval of the Procedure for Determining the Size and Boundaries of Water Protection Zones and the Regime for Conducting Economic Activities therein. Available online: https://zakon.rada.gov.ua/laws/show/486-96-%D0%BF#Text [Accessed on 07 November 2025]

[5] Order of the State Service of Ukraine for Geodesy, Cartography and Cadastre, (2021). On the Cancellation of Sectoral Regulatory Documents. No. 305 dated 18.06.2021. Available online: https://land.gov.ua/wp-content/uploads/2021/06/Наказ-305-від-18.06.2021.pdf [Accessed on 07 November 2025]

Thus, the Water and Land Codes prescribe the water cut (in the boundary period) as the primary CPS reference line; the water's edge on the shore is referred to as the shoreline. The water cut should be considered in two planes - vertical and horizontal. The first component characterizes the dynamics of the water level in height, and the second - the change of the level surface in the planned position. Note that when developing projects for establishing the boundaries of water protection zones and CPSs, only the planned position of the water cut in the boundary period is used. In this connection, there is a problem of setting the limit water level regardless of the actual position of the cut during the installation of the CPS.

Challenges in Defining Reference Lines for Small and Ephemeral Water Bodies

Because the Land and Water Codes do not define the establishment of the CPS for small rivers of the steppe and mountain zone, as well as shallow ponds and lakes that may dry up in certain periods of the year, the question of the reference line of the CPS for this group of water bodies remains open. In this case, the line of the bed of linear water bodies can be taken as the CPS reference line. In flat terrain, flood events can expand water-body area by 5–20×, calling into question whether protective zones based on the average long-term water level are feasible (Kravchuk, 2023; Pereoslyak and Malakhova, 2013). Establishing an appropriate reference system is critical for determining CPS widths in practice. It is known that among the elements of the hydrological regime of water bodies, the water level indicator, which characterizes the fluctuations of the water mass in different time intervals, occupies a prominent place. These time intervals (phases) are distinguished by water content: watershed (high water content), summer and winter border (low water content), and rainy floods. Plain rivers of moderate latitudes are usually characterized by all four phases; mountain rivers mainly have two phases: flood and low tide.

Cartographic Standards and the Accuracy of Shoreline Depiction

Cartographic and regulatory guidance indicates that, on topographic maps (scales 1:10,000 to 1:1,000,000), lake and river shorelines should represent the water level in the boundary period, whereas large reservoir shorelines should correspond to the normal support level[6] (Basic provisions, 1999). At the same time, the accuracy of the image of the coastline will be determined by the scale of the map. On 1:5,000 and 1:2,000 plans, river and lake shorelines are typically shown at low-water positions (most persistently low levels); on 1:1,000 and 1:500 plans, shorelines reflect the position at the time of survey[7]. The shorelines of reservoirs are shown along the line of their normal supporting horizon (NSH). If the water level in the reservoir is below the design mark and remains in the same position for several years, then the line of the actually reached level is taken as the coastline. For reservoirs with a variable water horizon that has not reached the NSH level, it is customary to consider the line that corresponds to the average long-term level of this reservoir,

[6] Basic provisions for creating and updating topographic maps of scales 1:10000, 1:25000, 1:50000, 1:100000, 1:200000, 1:500000, 1:1000000, (1999). Approved by the order of the Main Department of Geodesy, Cartography and Cadastre of Ukraine No. 156 dated 12.31.1999

[7] Procedure for topographical surveying at scales of 1:5000, 1:2000, 1:1000 and 1:500 (2025) Order of the Ministry of Agro-Industrial Policy and Food of Ukraine dated April 17 N 1675 Available online: https://zakon.rada.gov.ua/laws/show/z0868-25#Text [Accessed on 14 December 2025]

determined from the materials of the hydrometeorological service, as the shoreline. Thus, if the coastline changes only the height position and does not change its position in the horizontal (plan) plane, then it can serve as the starting (baseline) reference line of the CPS. In this case, the CPS width is determined directly during topographical and geodetic surveys for land management. For reservoirs with a variable planned position of water, it is customary to consider the line that corresponds to the average long-term level of this reservoir, determined from the materials of the hydrometeorological service, as the shoreline. In this case, additional hydrographic studies should be conducted to determine the planned position of the original reference line.

The coastline of the sea on topographic maps must correspond to the cut line of the water at its highest level during high tide or surf. Changes in climatic conditions and the hydrological regime of water bodies lead to changes in the coastline of natural reservoirs and, hence, to the loss of the degree of trust in cartographic materials on scales of 1:10000, 1:25000, and 1:50000, which in some cases are outdated and do not reflect the real state of the configuration and hydrological regime. The coastline of seas without tides (as well as with tides less than 0.5 m high) is considered to be a line that corresponds to the average long-term sea level; in the process of topographic works, it can be depicted when the water area is calm – along the water cut line – and when it is disturbed - along the surf line. The accuracy of hydrographic surveying is regulated by the decisions of the International Hydrographic Organization (IHO) in Monaco and distributed by Special Resolution No. 44. IHO establishes several degrees of accuracy of bathymetric survey. Under IHO Standards (2008)[8], the planned positional error for coastline determination is typically 10–20 m.

Institutional and Methodological Inconsistencies

Different agencies use varying methodological approaches for depicting shorelines of small reservoirs, large reservoirs, and seas. First of all, this is explained by the departmental approaches of individual administrative structures in terms of ensuring the duties assigned to them. In particular, one of the important functions of water management organizations is to provide the population of the country with high-quality water resources, and hence the choice of the threshold level, which allows establishing the critical mass of the water resource. Conversely, for maritime navigation safety, it is essential to determine and map the high-water level, which is accordingly reflected on topographic and hydrographic charts. At the same time, the primary objective of land management is to design measures and instruments that ensure the protection, rational use, and sustainable development of land resources across regions and territories. Therefore, unified methodological guidelines are needed for CPS delineation that align with societal needs and contemporary principles of sustainable land governance. The review indicates that CPS delineation for lakes, ponds, and rivers should rely on updated topographic maps at scales of 1:10,000, 1:5,000, 1:2,000, 1:25,000, or 1:50,000, which can provide sufficiently accurate shoreline representations. In contrast, for large reservoirs, seas, and estuaries, determining CPS boundaries requires additional investigations to establish the planned water surface boundary with acceptable accuracy. Where necessary, this must be supported by specialized engineering,

[8] IHO Standards for Hydrographic Surveys (2008). (S-44), 5th edition, February 2008.

topographical–geodetic, and hydrographic surveys to ensure the reliability of the resulting boundary lines.

Note that modern legal documents do not provide an answer to one of the main key questions regarding the accuracy of marking the boundaries of CPS and water protection zones. In the monograph (Perovych and Say, 2017), studies are partially given that relate to the accuracy of determining the width of the CPS depending on the configuration of the water body and the monetary value of the CPS lands.

Statement of the problem

The accuracy of establishing the width of the CPS is an integral part of the legal toolkit, which establishes the geometric parameters of these zones, which in turn ensures their effective spatial planning and the resolution within their limits of a whole series of nature protection, ecological, economic and other issues related to the conduct of construction, the resolution of land disputes, water protection obligations, etc. Given the insufficient study of this issue, a search for ways to solve it was made.

A Methodological Approach to establishing CPS limits

The design of CPS and water protection zones requires the availability of appropriate cartographic material. This, in turn, leads to the need to carry out a whole series of organizational, analytical, and engineering-technical measures regarding the quality performance of project work and, ultimately, its implementation. For this purpose, in the general structure of the land management project, a project of topographical and geodetic support (PTGS) for establishing boundaries should be developed. We will present the technological model of the solution to the given problem (Figure 1).

This model includes three main stages: the first preparatory stage, which forms a database of input data; the second, chamber design; the third, field work; and the fourth, processing of field materials and formation of a technical report.

The first stage includes aspects of regulatory regulation of the formation of water protection zones and CPS; topographical and geodetic study of the area of works with a special emphasis on the availability of points of the State Geodetic Network and topographic plans or maps for the object of works; and research of the passport and hydrography of the water body with the mandatory establishment of water level and flood level marks. In the absence of a water body passport and relevant cartographic materials, the project provides for additional topographic and hydrographic surveys. An important stage of the project is the camera design, which involves creating the appropriate topographic plan or map of the project. On the topographic plan, in accordance with the planned position of the boundary water level mark, a horizontal line (isobath) is drawn, which will be the reference line of the outer border of the CPS in the following. At this stage, using the available cartographic material, characteristic points (bends, dips, etc.) are drawn on the boundary level curve. In accordance with the established points, depending on the regulatory documents regarding the width of the CPS, the locations of the border marks of the outer border of the CPS are plotted on the topo plan, and their coordinates are determined graphically. The segment from a

boundary-level point to the corresponding CPS point must be normal to the tangent of the boundary-level curve at that point. Note that the mark of the boundary level does not have a principled solution when determining the CPS for deep-sea objects, since in this case the position of the level surface changes only in height, and in the plan view it is unchanged. In the case of shallow water objects, the planned position of the boundary level can be established on the basis of existing topographical-geodetic or hydrographical data. For drying reservoirs, the channel centerline may serve as the planned limit-water position.

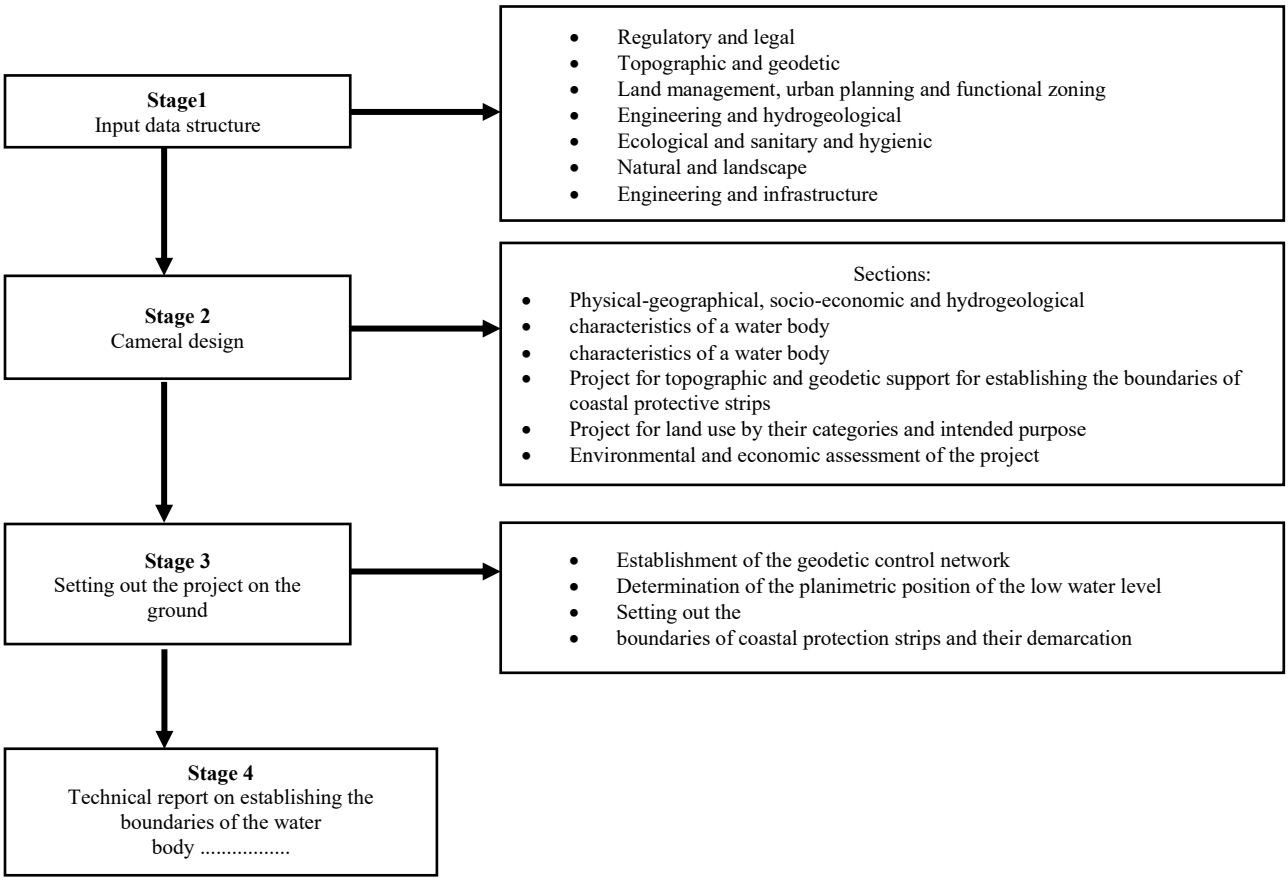
Stage1
Input data structure
Regulatory and legal
Topographic and geodetic
Land management, urban planning and functional zoning
Engineering and hydrogeological
Ecological and sanitary and hygienic
Natural and landscape
Engineering and infrastructure
Stage 2
Cameral design
Sections:
Physical-geographical, socio-economic and hydrogeological
characteristics of a water body
characteristics of a water body
Project for topographic and geodetic support for establishing the boundaries of coastal protective strips
Project for land use by their categories and intended purpose
Environmental and economic assessment of the project
Stage 3
Setting out the project on the ground
Establishment of the geodetic control network
Determination of the planimetric position of the low water level
Setting out the
boundaries of coastal protection strips and their demarcation
Stage 4
Technical report on establishing the boundaries of the water body .....

Figure 1: Technological model of setting CPS limits

After that, they proceed to the design of the reference geodetic network. The reference geodetic network is created according to the intended purpose. It should cover all or part of the territory of the water body, ensuring, if necessary, topographical surveying at the stage of search and performance of marking works, as well as carrying out the project in nature in accordance with the technical task. Such an engineering geodetic network has several characteristic features, in particular:

- It can be created in a conventional coordinate system with the following binding to the points of the state geodetic coordinate system;
- The form of the network and the methods of its construction are largely determined by the physical and geographical characteristics of the territory and the configuration of water bodies;

- The accuracy of construction of the reference geodetic and the methods of its construction must correspond to the accuracy of establishing the corresponding border marks.

Similarly, to the proposed methodology, the design of establishing the boundaries of water protection zones can be carried out. In our opinion, projects of boundaries of water protection zones in flooded areas should include areas where high water levels are possible. This approach will allow more rational use of land resources, which, according to hydrometeorological data, are at risk of flooding. This will allow a more constructive approach to the procedure of land administration, its structuring according to infrastructural, urban planning, environmental, and other factors, which in the end should lead to significant savings in financial and material costs in the process of life. After completing the design of the reference geodetic network and determining point coordinates using graphical or instrumental methods, it becomes possible to develop a marking layout. This layout provides the basis for subsequently transferring the designed boundary points onto the ground with the required accuracy.

The third stage includes technical procedures related to the implementation of project solutions in kind. At this stage, it is important to determine the methods of construction of reference geodetic networks that would satisfy the accuracy of establishing the planned position of boundary marks. Note that in modern conditions, GNSS methods are most widely used; however, in built-up areas, areas covered with high vegetation, and complex mountainous terrain, the use of this method can be problematic, and in that case, classic methods of triangulation, trilateration, and polygonometry can be used.

The final stage of the presented model is a technical report, which presents the materials of the previous stages and outlines the boundary signs installed on the site. Note that decision-making regarding the width of the CPS of certain types of water bodies is usually regulated by national legal acts.

Accuracy Assessment

Unresolved issues remain regarding the accuracy of determining the planned position of CPS boundary marks. According to the proposed methodology, the limit graphic mean squared error (MSE) in locating the planned position of points corresponding to the limit water level is given by:

$m_y = 0.2mm \cdot M$ (Ostrovsky, Moroz and Tarnavskyi, 2007), where M is a dimensionless value that characterizes the scale of a topographic plan or map. For example, when using a topographic map with a scale of 1:10,000 m_y= 2 meters.

Combined Design Error: The design of the CPS boundary marks incorporates two primary sources of error:

The error in determining the boundary water level, and the error associated with projecting the normative distance from the boundary level to the CPS line. Thus, the total mean squared error of the planned position of a designed boundary mark is:

$$m_r^2 = m_y^2 + m_p^2, \quad (1)$$

Where m_r- mean squared error of the planned position of the designed boundary sign; m_y- the mean squared error of determining the planned position of the water cut; m_p- the mean squared error of the boundary sign design.

Taking $m_y = m_p = m$ for graphic design, we get $m_k^2 = 2m^2$ or $m_r = m\sqrt{2}M$. Thus, taking into account the scale of the map on which the design is conducted, we have

$$m_r = 0.22\text{мм}\sqrt{2}M = 0.28\text{ммM}, \quad (2)$$

The resulting value of the mean squared error of the planned position of the boundary mark CPS, in addition to the design errors, will include errors due to the displacement of the designed position of the boundary marks in nature. Thus, the mean squared error m_z of the planned position of the boundary mark placed in kind on the terrain will be:

$$m_z = m_r + m_v, \quad (3)$$

Where m_v is the mean squared error of the removal procedure.

Given that modern geodetic network construction methods typically provide much higher accuracy than the design stage, the implementation errors can often be considered negligible. Therefore, expression (2) is generally sufficient for practical use. For example, when using a map with a scale of 1:10,000 to design, the error of the planned position of the border mark will be about three meters, and when using a topographic plan with a scale of 1:5,000 - 1.5 m.

Research related to the accuracy of establishing the CPS of the Black Sea deserves special attention. In the Black Sea, the tides are almost imperceptible. They occur independently of the World Ocean, and the range of tidal and tidal fluctuations ranges from three to ten centimeters (Kuznets, 2025), which makes it possible to use dependence (2) to calculate the accuracy of establishing CPS limits.

Fieldwork and Geodetic Network

Fieldwork includes constructing a site reference geodetic network per the previously described recommendations. The reference geodetic network serves as the basis for carrying out the project in nature in accordance with the developed marking drawings, as well as carrying out, if necessary, topographic-geodetic, engineering-hydrological, and engineering-hydrographic works. Engineering and hydrological searches are also carried out for the creation of recreation areas, research on water exchange, the hydrochemical state of the reservoir, etc. Hydrographic engineering studies include work related to water level changes, which is especially important when establishing water protection boundaries.

In the event of a lack of topographical material for this object, this geodetic justification can serve as the basis for a topographic-geodetic survey of the area, which will precede the CPS camera design. For surveys of rivers, lakes, reservoirs, and shelves, the initial geodetic base should tie to national planimetry and elevation control points. To perform all the specified types of work on the territories of water bodies, a geodetic network is

created, the shape and scheme of which depend on specific conditions and the nature of future work.

The reporting documentation includes: information on the input database; a situational plan with a marked search area; a scheme of plan-elevation geodetic network; engineering and topographic plans of the coastal strip and hydrotechnical structures; schemes of marking drawings; catalogs of coordinates of the geodetic network; calculation materials, alignment, and accuracy assessment; scheme and steps of fixed border signs; and explanatory notes to the completed works.

Approbation of research results

Case Study: Formation of the Coastal Protective Strip (CPS) of Lake Synevyr

The methodology was tested by delineating the CPS for Lake Synevyr. Synevyr, one of the largest Carpathian lakes, lies in the Inner Gorgan massif at 989 m elevation (Figure 2). It is a World Heritage Site and is part of the Synevyr National Nature Park. More than 10,000 higher vascular plants, 43 species of mammals, 91 species of birds, 7 species of reptiles, 12 species of amphibians, 24 species of fish, and more than 10,000 invertebrate living organisms are protected in the park. The "Glukhanya" and "Zamshatka" oligotrophic swamps are located on the territory of "Synevir". The water surface area of the lake reaches about 7 hectares, and the maximum depth is 22 m. The volume of water in Synevyr is about 400,000 cubic meters. Two types of fish live in the lake: goliak and trout. The water in the lake is free of chlorides, has a distinctive taste, and reaches temperatures of up to 20°C in summer.

Figure 2: General view of Lake Synevyr (*Source:* Tours of Ukraine, 2020)

A topographic map with a scale of 1:10,000 with a relief section of 10 meters served as the planning and topographic materials for the design of the CPS (Figure 3). According to regulatory documents, the width of the CPS for Lake Synevyr, with an area of 7 hectares, should be at least 50 meters.

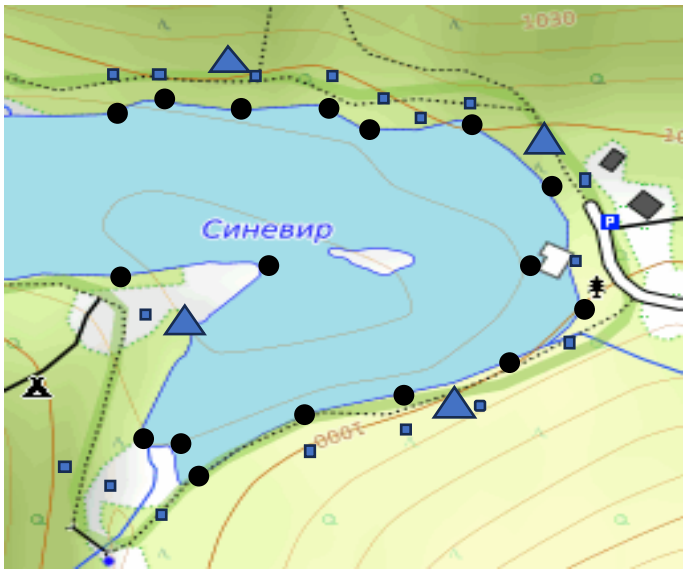

Figure 3: A fragment of the CPS project of Lake Synevyr points to the determination of the threshold level; sets of reference geodetic networks, border marks.
Where: ● points of determination of the threshold level; ▲sets of reference geodetic networks; ▪ border marks

The picture (figure 2) shows a fragment of the CPS project of Lake Synevir. Using a topographic map, the points that best describe the configuration of the boundary water level were determined. Note that according to the scale of the map, the accuracy of the planned position of the boundary level points, determined by formula (2), will be 3 meters. The projected boundary marks plotted on the map carry an additional similar positional error of 3 meters. Therefore, the combined design error in locating boundary marks is:$3м\sqrt{2} = 4.2$ meters. Hence, the reference geodetic network should ensure the accuracy of taking boundary marks into the ground with an error of not more than 4-5 meters. To ensure such accuracy, it is necessary to build a special reference geodetic network. At the same time, taking into account the fact that geodetic work is conducted in a closed forest area, where the application of GNSS methods is difficult, the reference geodetic network is built using classic ground methods. In this case, it is proposed to build a special geodetic network by the method of polygonometry with an accuracy that is an order of magnitude higher than the accuracy of determining the coordinates of boundary marks, in compliance with the existing regulatory requirements.[9]

From the reference points, according to the marking drawings, the border marks are carried out in kind, which allows for to formation of a CPS border with a width of 50 meters on the terrain with an error of up to 5 meters. In the presence of cartographic

[9] Supra note 4, 7

materials on a scale of 1: 5,000, the accuracy of placing boundary marks in nature will double and reach 2 meters.

Discussion

Water–land relations are complex because water bodies comprise both the water mass and the adjoining land, which interact dynamically. Water objects and the lands of the water fund on which they are located are subject to the influence of various destructive factors. The legal regime of the use of water bodies should be considered in conjunction with the legal regime of the lands of the water fund, which together can be called water-land relations, which are a single complex object of legal regulation, in which land and water are both objects of nature use and are the subject of ecological relations. The issue of the protection of water systems can be solved to a large extent by the current legal norms.

In Ukraine, the basin principle of managing the use, protection, and reproduction of water resources, which is based on the principles of the Framework Water Directive of the European Union (European Commission, 2000), is legally enshrined. This model of water resources management provides for the development of water policy directions. Basin councils carry out a full range of functions related to water resources management, including studying the state of water resources, water protection, ensuring protection against harmful effects of water, water monitoring, certification, cadastre, and others. Unregulated coastal development for recreation creates hazardous conditions for water-land systems. In order to protect water bodies from pollution, silting, and depletion, etc., the legislation followed the path of creating a legal regime for the width of water protection zones and coastal strips. At the same time, the accuracy of establishing these dimensions has not been determined, which leads to the ambiguity of their definition, which in turn gives rise to a complex of legal disputes and legal conflicts regarding the belonging of individual land plots to the CPS and their respective legal status.

This study shows that establishing CPS width on the ground requires dedicated methodological approaches to define the baseline (reference line). In particular, according to the International Standard[10], the error in determining the baseline of the seas is related to tidal processes and is within 10-20 meters. However, as studies show, the error of the initial line of the Black Sea reaches 1-2 meters. Thus, establishing CPS accuracy parameters requires specific determinations of the errors of the original lines for individual water areas of the seas.

For water-pressure reservoirs, deep-water objects, in which the water level fluctuates only in the vertical plane, as well as drying rivers and streams, the error in the specified widths of the CPS will depend mainly on the accuracy of the scale of the topographic-geodetic survey of the territory. For topographic plans, the average errors in the position of boundary marks on the plan relative to the nearest points of the shooting base should not exceed the values presented in table 1[11].

[10] Supra note 9
[11] Supra note 4, 7

Table 1: Errors of CPS sizes of deep-sea and drying objects, m

Districts	*Scale 1: 1 000*	*Scale 1: 2 000*
Plain	0.50	1.00
Mountain and forest	0.75	1.50
Built up	0.40	0.80

For water bodies with the dynamics of a planned (horizontal) change in the position of the water cut, the problem of determining the amount of CPS width errors requires a special methodical approach, which includes a whole complex of hydrographic and topographic-geodetic works. The conducted studies showed that for this type of water bodies, the error in determining the width of the CPS depends on the scale of the available cartographic materials, and for scales of 1: 10 000 - 1: 5 000 it can be 4.5 - 1.5 meters.

Topographic surveying of the territory of the CPS can be carried out by the methods of tacheometry, GNSS observations, aerial surveying, laser scanning, combined methods, etc. Investigating the accuracy of determining the width of the CPS of various water bodies, it was established that there are no unified methodological approaches to the establishment of CPS and water protection zones in global practice. One of the most unresolved and debatable issues remains the problem of establishing baselines for determining CPS sizes.

Conclusions

An important aspect of the procedure for establishing the boundaries of CPS remains the question of the accuracy of establishing their dimensions (width), since these are territories of limited economic use that have protective water protection, ecological, and nature protection functions. Establishing at the official level the values of marginal errors in the CPS sizes of water bodies is an additional mechanism for solving in the right field several legal conflicts related to the belonging of individual land plots to the CPS. As a result of the conducted research, a method of establishing the boundaries of the CPS is proposed using cartographic materials that show the boundary level of the water cut of water bodies. For this purpose, a technological scheme of design, field, and chamber work is proposed.

Research has established that for marine water areas, the error in the established widths of CPS boundaries can range from 1 to 20 meters. For each marine water area, the position of the starting line should be determined independently. CPS width errors of water pressure reservoirs and deep-water objects, as well as drying rivers, depend on the scale of the territory mapping. For example, at a 1:1,000 scale, the error may be 1–2 m. For water bodies with dynamic planned horizontal shifts of the water cut, boundary-width error is strongly related to the cartographic scale: using 1:10,000 maps yields errors of 4–5 m. Baselines for different water-body types remain debatable and warrant further research.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

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Conceived and designed the research or analysis	Yes	Yes	Yes	Yes	No	No
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Contributed to data analysis & interpretation	Yes	Yes	No	No	No	No
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